

US008225497B2

(12) **United States Patent**
Johnson et al.

(10) **Patent No.:** **US 8,225,497 B2**
(45) **Date of Patent:** **Jul. 24, 2012**

(54) **PERMANENT MAGNET ROTOR
INSTALLATION SYSTEMS**

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/652,430**

(22) Filed: **Jan. 5, 2010**

(65) **Prior Publication Data**

US 2011/0162199 A1 Jul. 7, 2011

(51) **Int. Cl.**
H01F 13/00 (2006.01)
H02K 15/03 (2006.01)

(52) **U.S. Cl.** **29/732; 29/596; 29/598; 335/284**

(58) **Field of Classification Search** **29/596,**
29/732, 598; 335/284

See application file for complete search history.

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(57) **ABSTRACT**

Embodiments of the invention relate generally to rotor instal-
lation systems and, more particularly, to permanent magnet
rotor installation systems, including those having an in situ
magnetizer or magnet insertion device. In one embodiment,
the invention provides a rotor installation system comprising:
at least one magnetizer for permanently magnetizing a ferro-
magnetic material; and an arbor for receiving a rotor having at
least one portion including a ferromagnetic material, wherein
the at least one magnetizer is positioned relative to the arbor
to allow permanent magnetization of the ferromagnetic mate-
rial.

9 Claims, 8 Drawing Sheets

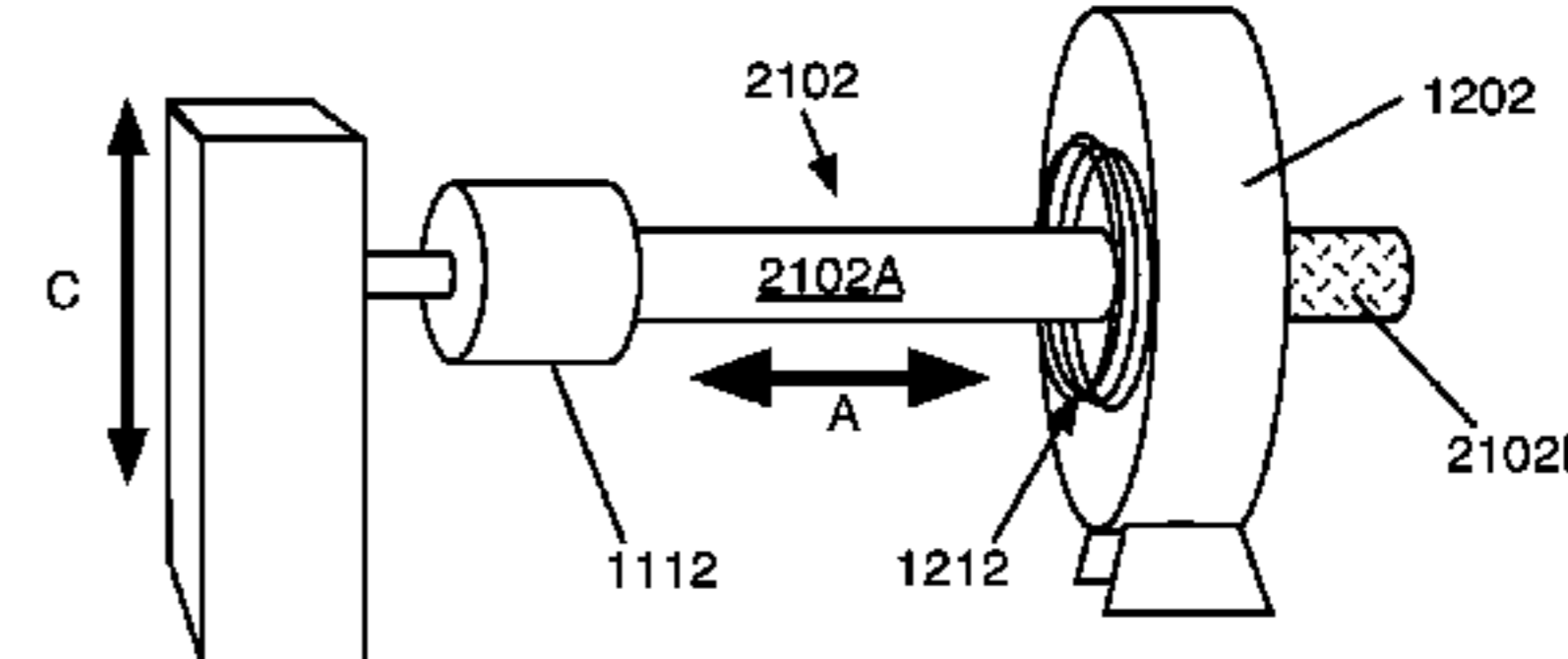
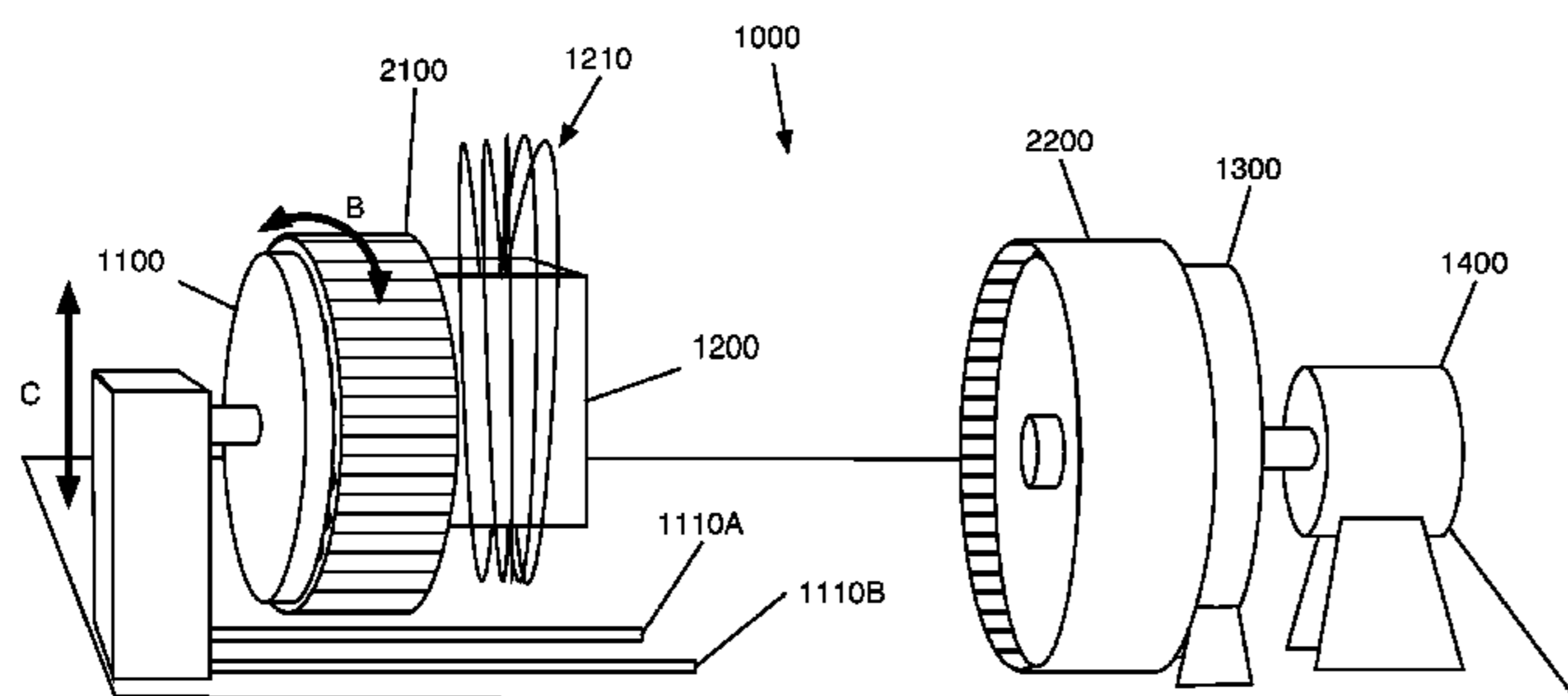


FIG. 1

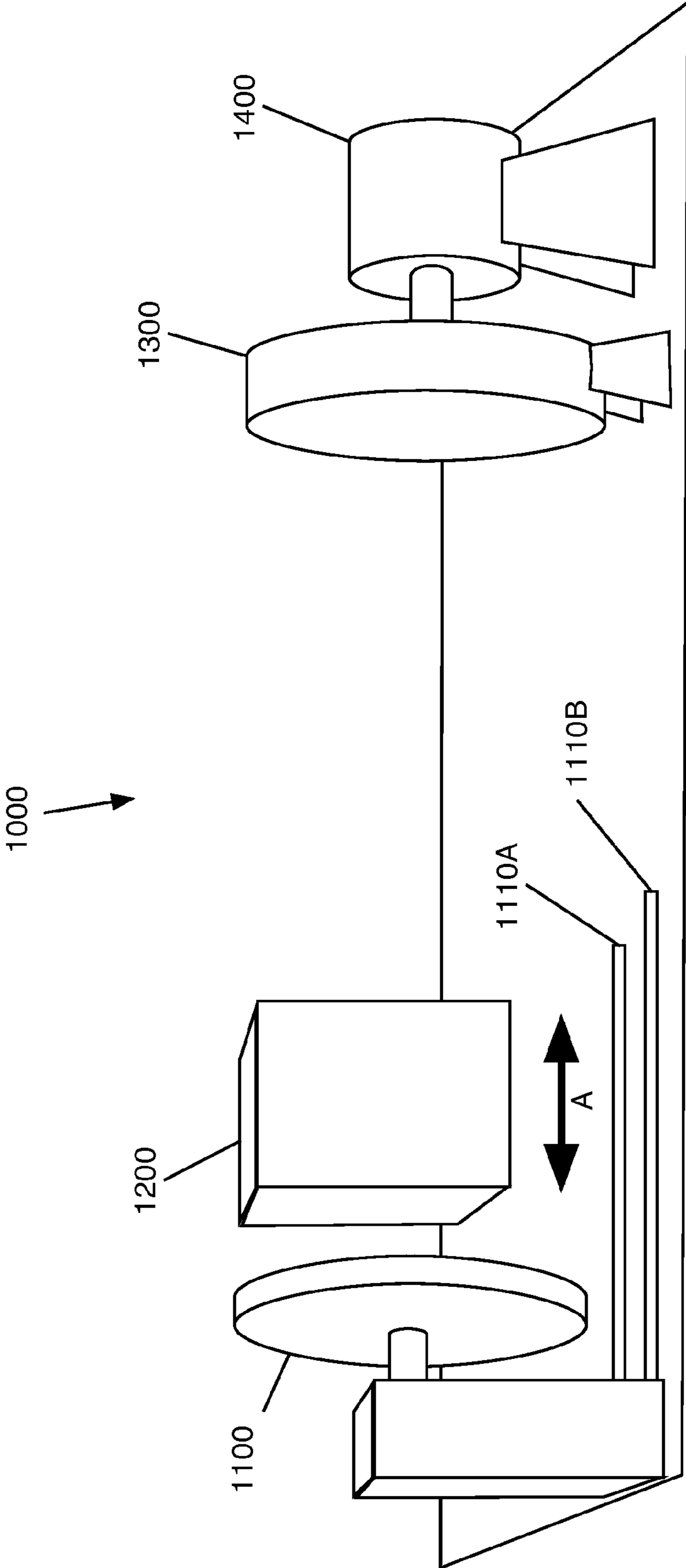


FIG. 2

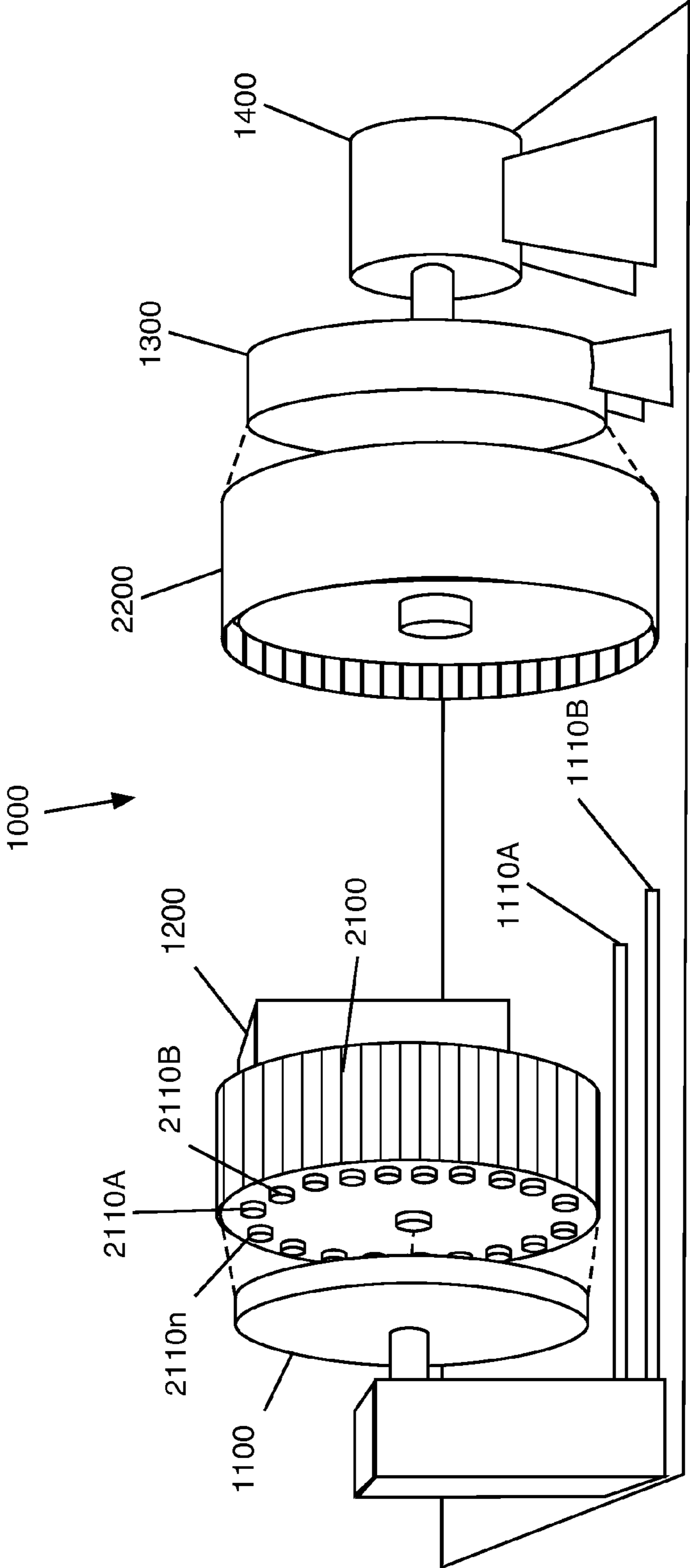


FIG. 3

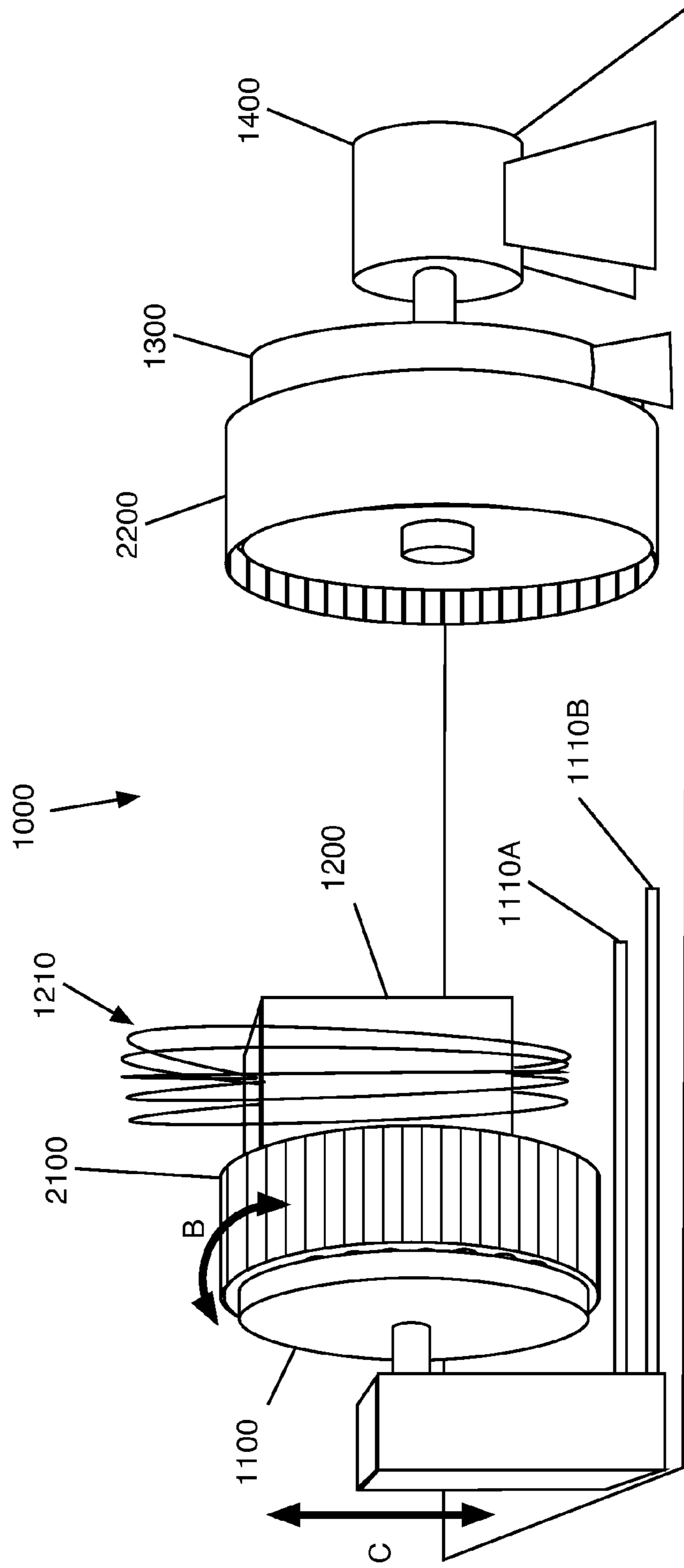


FIG. 4

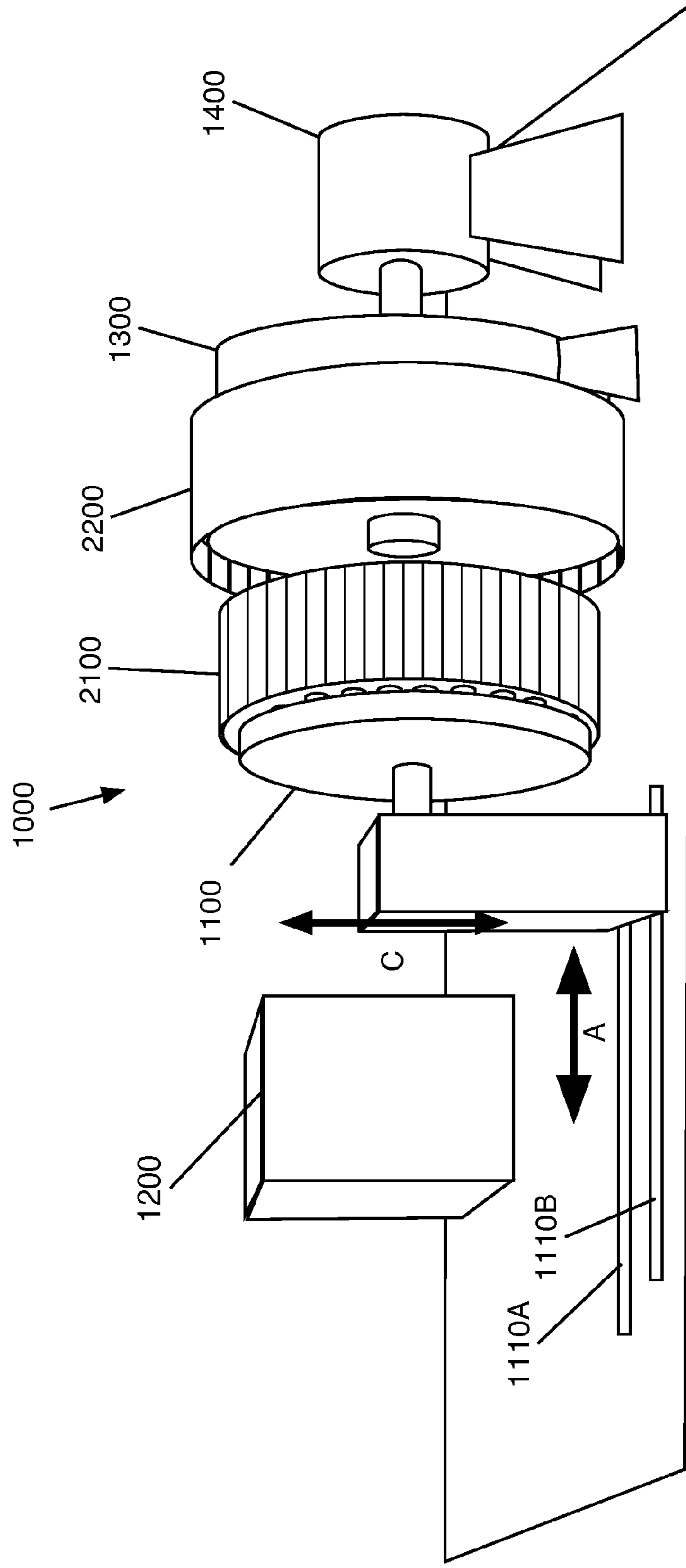


FIG. 5

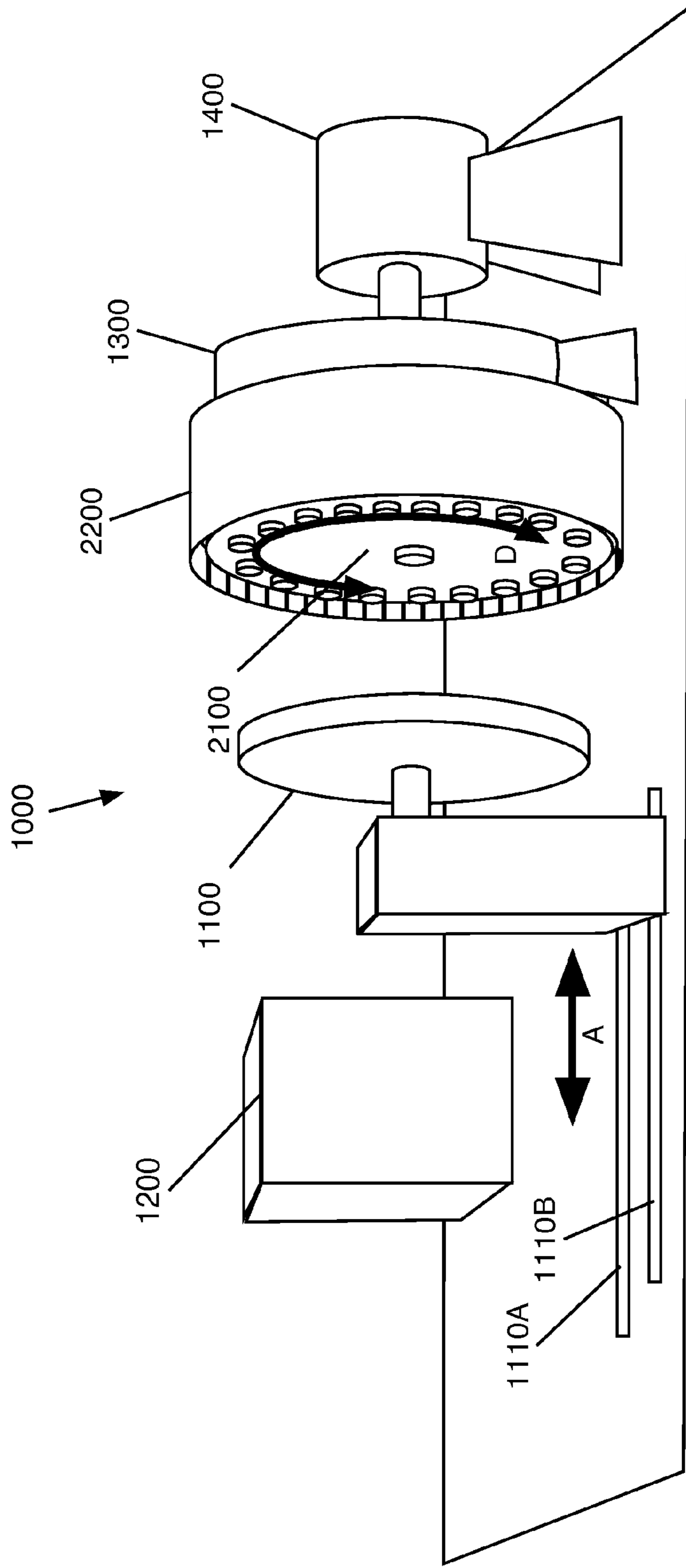


FIG. 6A

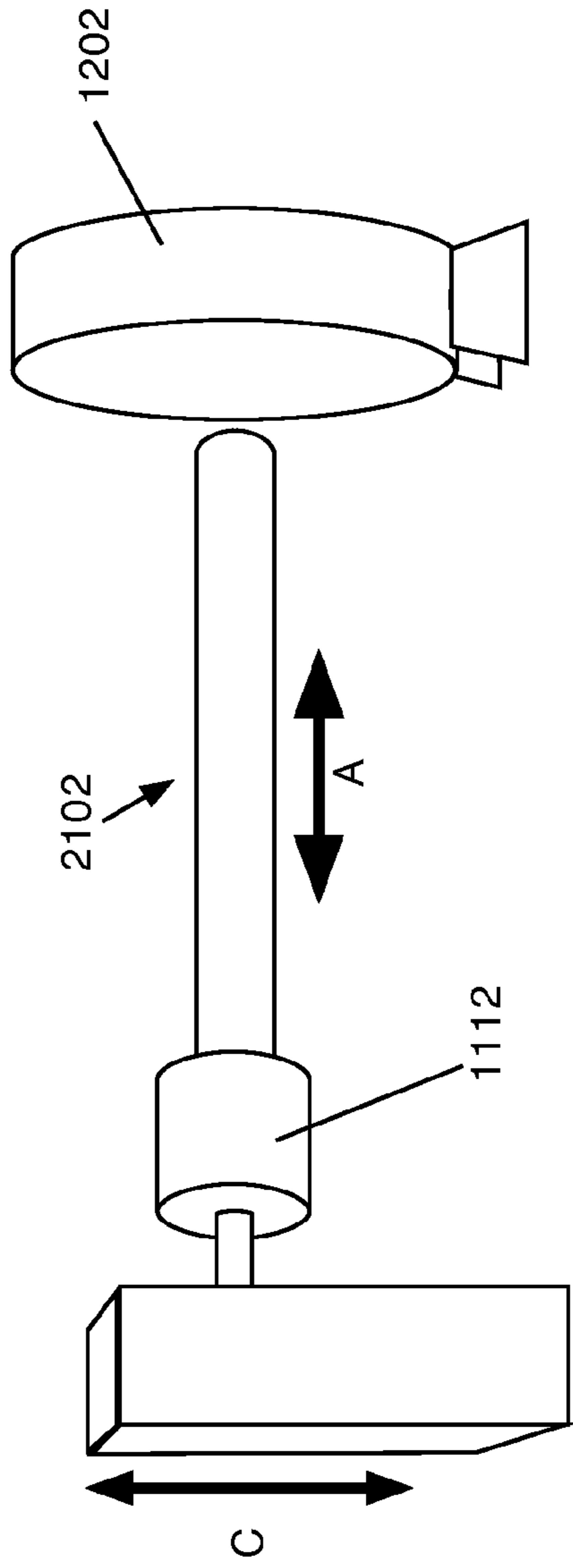


FIG. 6B

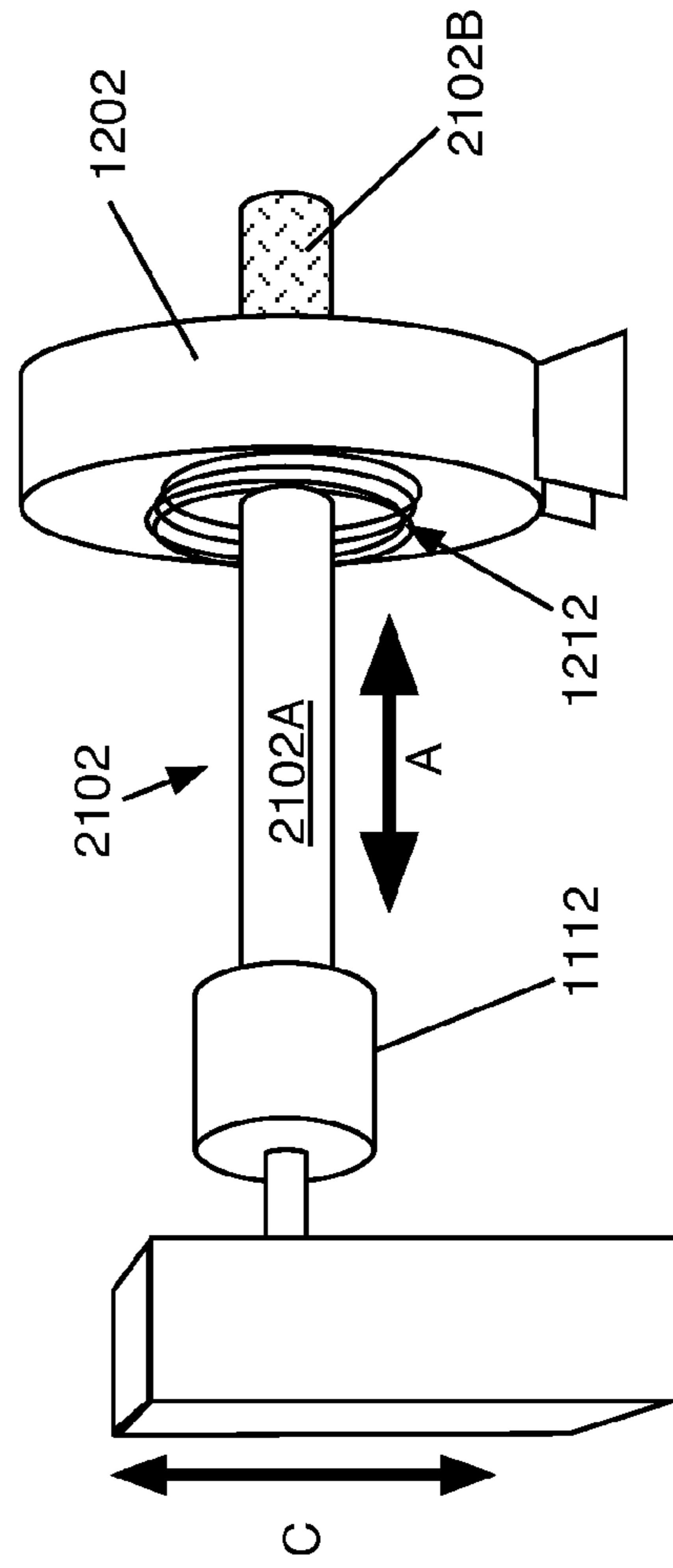


FIG. 8

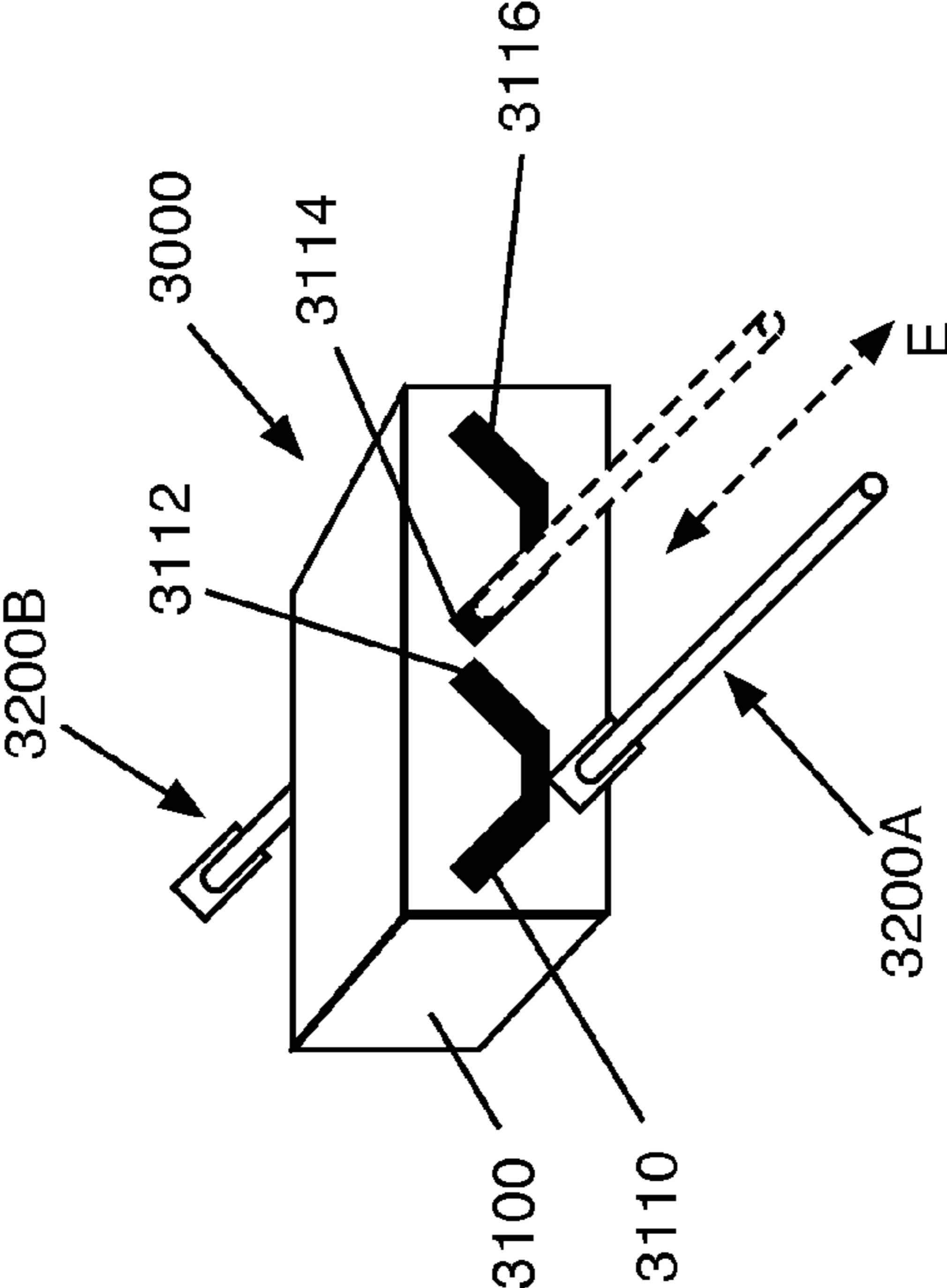


FIG. 7

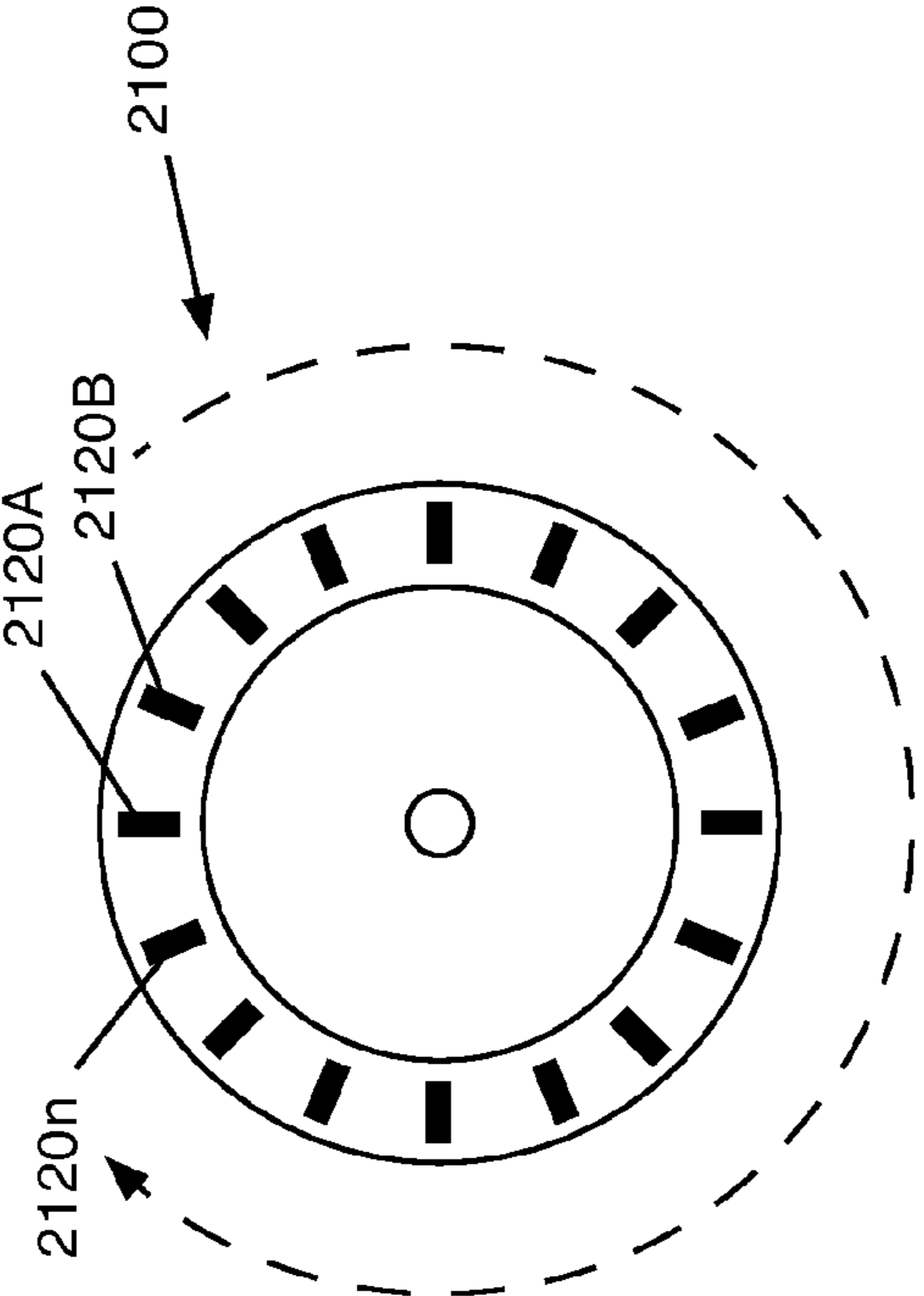


FIG. 9A

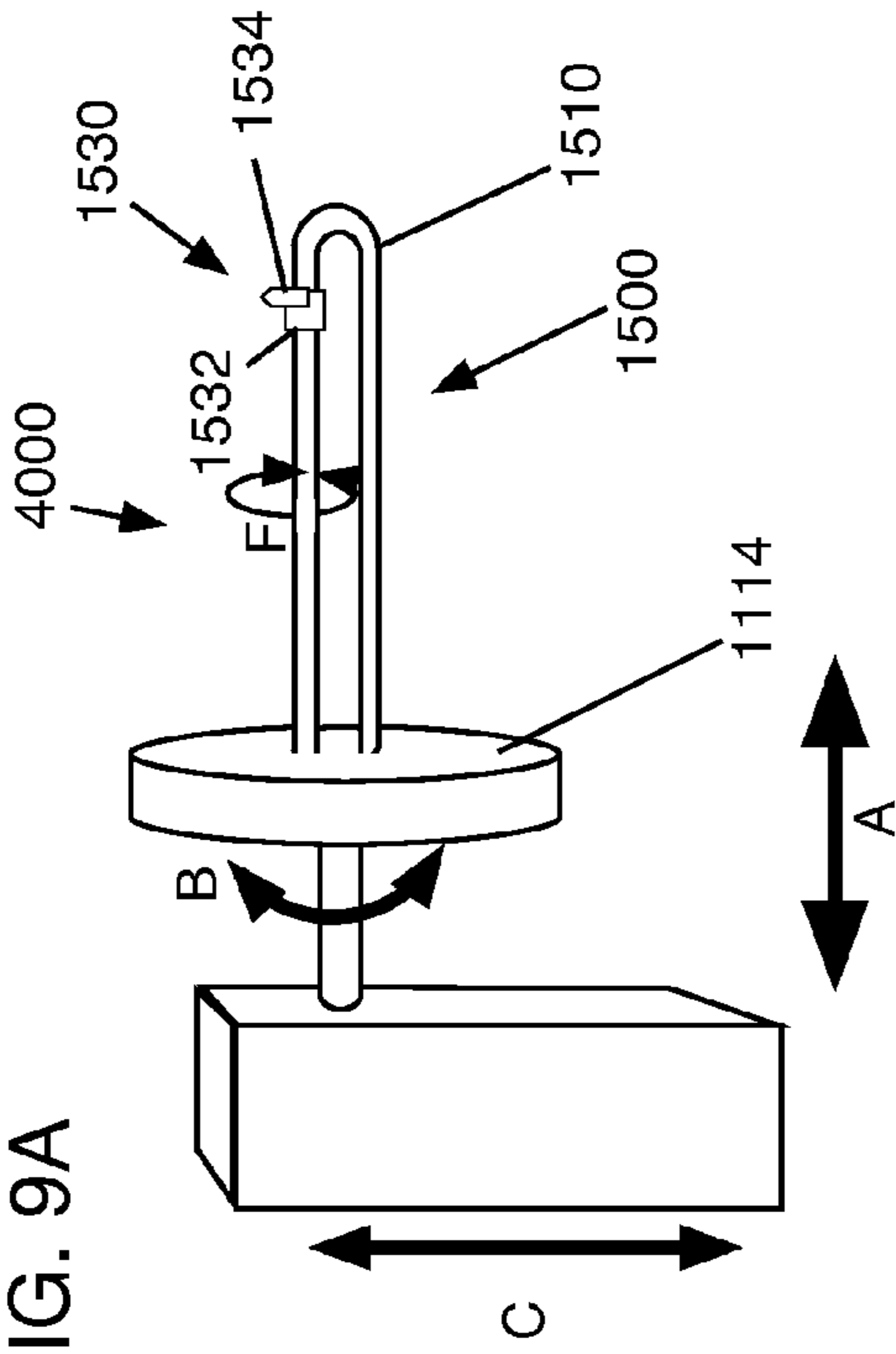


FIG. 9B

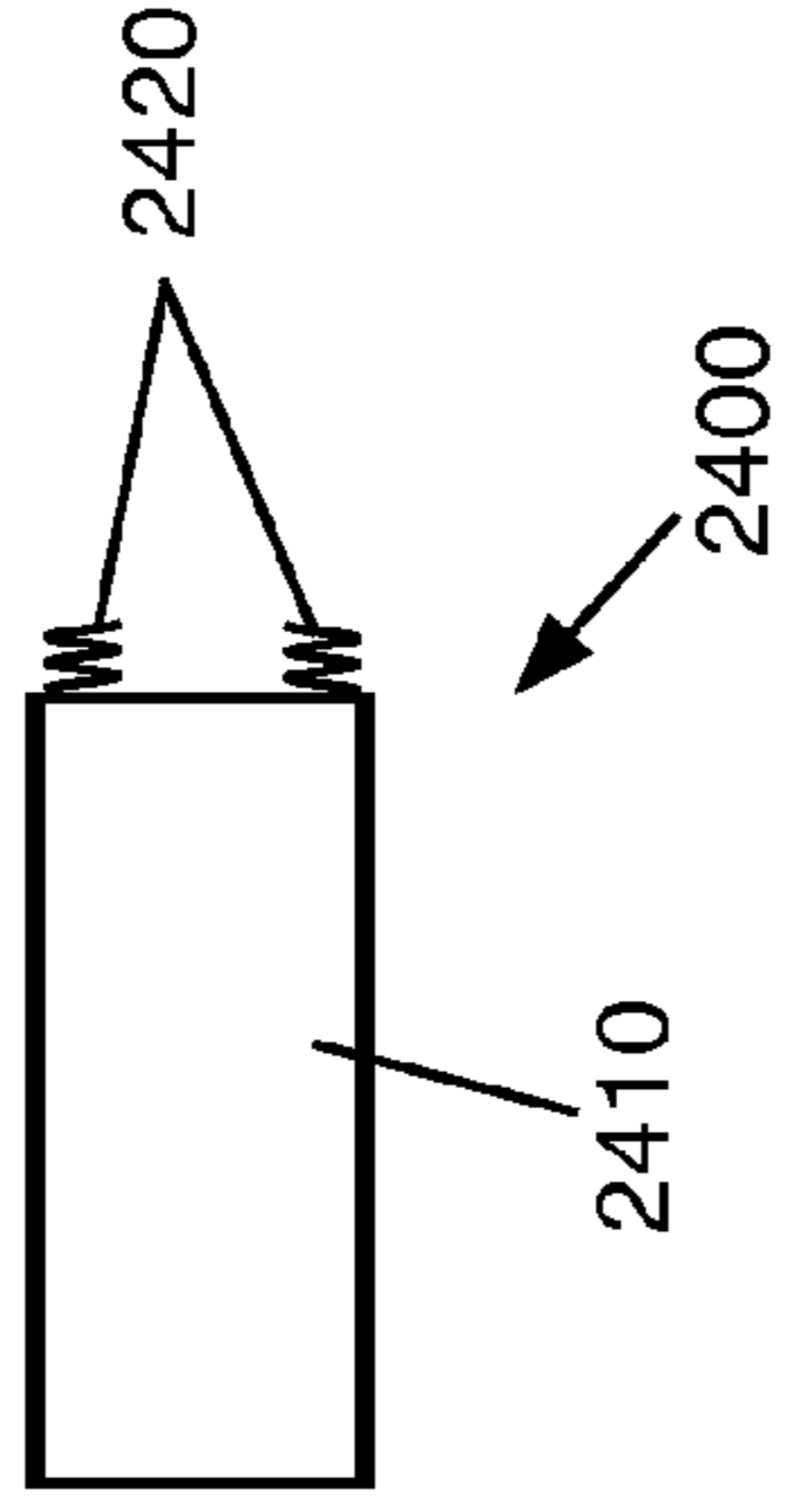


FIG. 9C

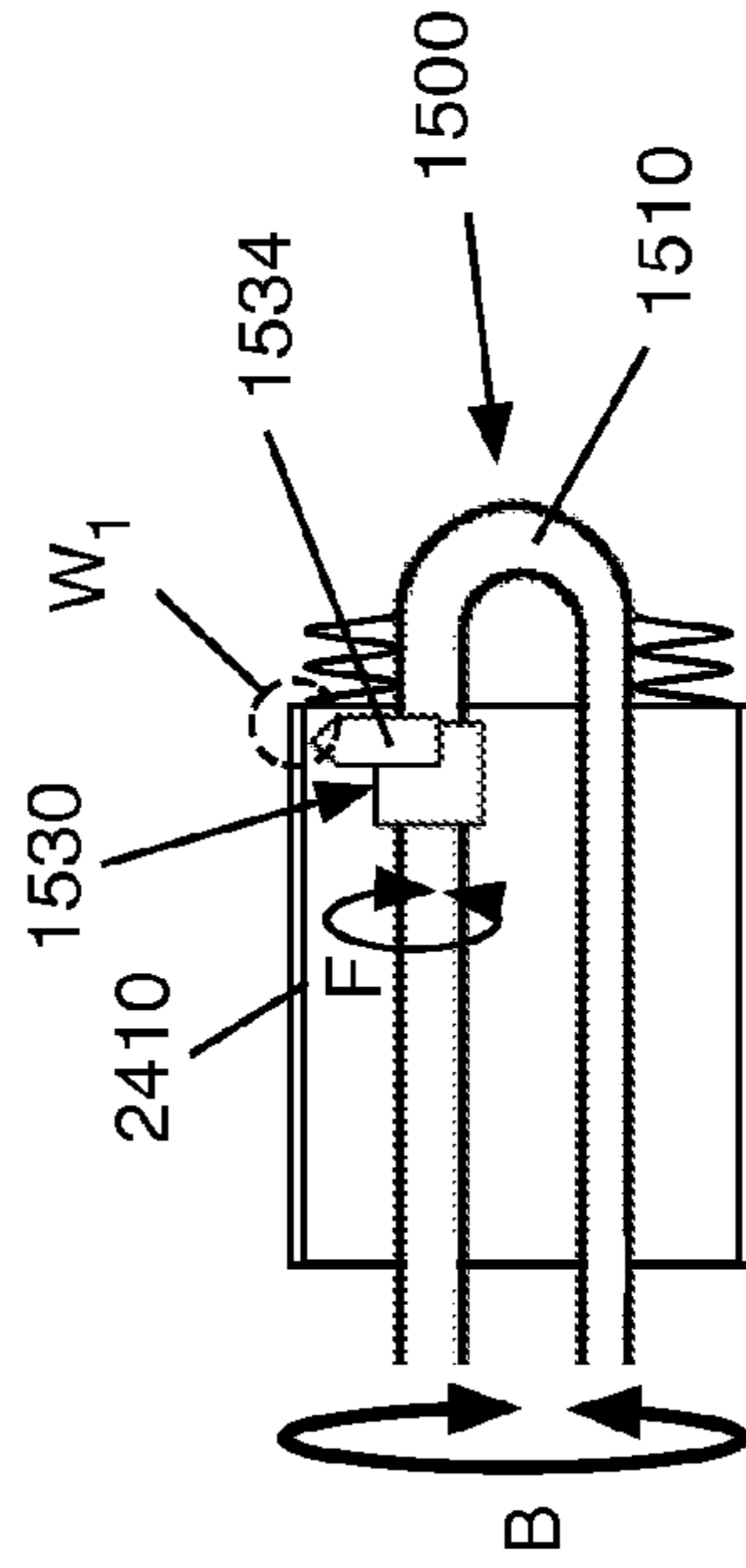
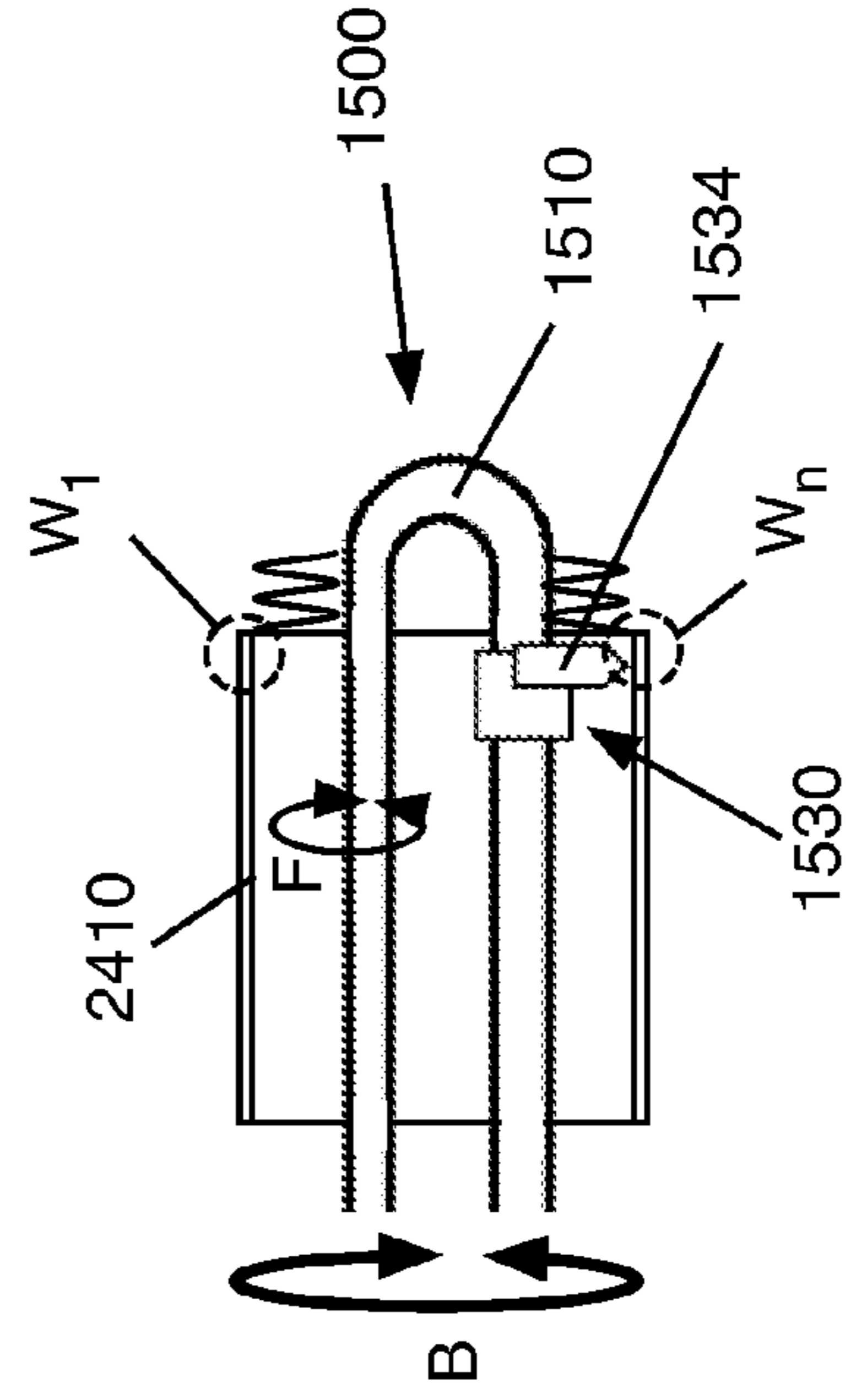


FIG. 9D



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PERMANENT MAGNET ROTOR
INSTALLATION SYSTEMS

BACKGROUND OF THE INVENTION

Embodiments of the invention relate generally to rotor installation systems and, more particularly, to permanent magnet rotor installation systems, including those having an in situ magnetizer or magnet insertion device.

The assembly of generators, motors, and other electrical machines containing permanent magnets requires special handling systems and safety precautions as the sizes and/or strengths of the magnets increase. That is, the large permanent magnets used in such machines exhibit magnetic forces and fields of such strength that their handling is hazardous to those involved in assembling the machines. The handling systems and safety precautions such assembly requires increase its cost and complexity.

BRIEF DESCRIPTION OF THE INVENTION

In one embodiment, the invention provides a rotor installation system comprising: at least one magnetizer for permanently magnetizing a ferromagnetic material; and an arbor for receiving a rotor having at least one portion including a ferromagnetic material, wherein the at least one magnetizer is positioned relative to the arbor to allow permanent magnetization of the ferromagnetic material.

Another embodiment of the invention provides a rotor installation system comprising: an arbor for receiving a rotor; and a magnet insertion device for inserting into the rotor a plurality of permanent magnets.

Still another embodiment of the invention provides a rotor installation system comprising: an arbor; an elongate member connected to the arbor and insertable inside a tubular member; and a welding device connected to the elongate member for forming at least one welded connection within the tubular member.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of this invention will be more readily understood from the following detailed description of the various aspects of the invention taken in conjunction with the accompanying drawings that depict various embodiments of the invention, in which:

FIGS. 1-5 show a rotor installation system according to an embodiment of the invention;

FIGS. 6A-6B show a rotor installation system according to another embodiment of the invention;

FIG. 7 shows a front view of a rotor;

FIG. 8 shows a magnet insertion device used in another embodiment of the invention and adapted to insert one or more permanent magnets into the rotor of FIG. 7; and

FIGS. 9A-9D show components of a rotor installation system according to yet another embodiment of the invention useful in forming welded connections between components of an electrical machine.

It is noted that the drawings of the invention are not to scale. The drawings are intended to depict only typical aspects of the invention, and therefore should not be considered as limiting the scope of the invention. In the drawings, like numbering represents like elements between the drawings.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1-5 show an illustrative operational method of magnetizing and installing a rotor using a system according to one

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embodiment of the invention. Referring now to FIG. 1, a rotor installation system **1000** according to one embodiment of the invention is shown. The rotor installation system **1000** includes an arbor **1100** for receiving and securing a rotor, a magnetizer **1200** for magnetizing a ferromagnetic material within such a rotor, a support **1300** for a generator, motor, or similar device having a stator and into which the rotor will be installed, and a drive motor **1400** capable of rotating the rotor within the stator once installed. To facilitate installation of the rotor, the system **1000** further comprises rails **1110A-B** along which the arbor **1100** may move (i.e., along path A). Other components and/or modifications of the system **1000** will be known to one skilled in the art and are within the scope of the present invention. For example, the arbor **1100** itself or a portion thereof may be independently movable, obviating the need for the rails **1110A-B**.

In FIG. 2, a rotor **2100** is shown being attached to the arbor **1100** and a motor **2200** having a stator being attached to the support **1300**. As can be seen, the rotor **2100** includes a plurality of ferromagnetic materials **2110A, 2110B . . . 2110n** along its periphery. The ferromagnetic materials **2110A-n** may include, for example, one or more of iron, nickel, cobalt, aluminum alloys of iron, aluminum alloys of nickel, aluminum alloys of cobalt, ceramic mixtures containing iron, ceramic mixtures containing nickel, ceramic mixtures containing cobalt, and neodymium-iron-boron alloys. These materials are provided merely for purposes of illustration and are not intended to be limiting. Other ferromagnetic materials will be known to those skilled in the art and are within the scope of the invention.

In FIG. 3, a magnetic field **1210** is produced by the magnetizer **1200**, the magnetic field **1210** being of sufficient strength to impart to the ferromagnetic materials **2110A-n** a degree of magnetism. For example, in the embodiment of FIG. 3, the arbor **1100** moves the rotor along path B (i.e., in a peripheral direction) to incrementally expose portions of the ferromagnetic materials **2110A-n** to the magnetic field **1210**. That is, the arbor **1100** rotates the rotor **2100** through the magnetic field **1210** to magnetize the ferromagnetic materials **2110A-n**. In some embodiments, it may be desirable, during magnetization, for the arbor **1100** to also be movable along path C (i.e., in a substantially vertical direction) to provide concentricity of the rotor **2100**. Such movement along path C may also aid in installation of the rotor **2100** into a stator of the motor **2200**, as will be described below.

FIG. 4 shows the rotor **2100**, with its ferromagnetic materials now magnetized, being installed into the stator of the motor **2200**. Such installation is accomplished, in the embodiment shown here, by moving the arbor **1100** along path A (i.e., in a substantially horizontal direction) using the rails **1110A-B** and, if necessary, along path C, in order to properly align the rotor **2100** and stator. Movement along either or both of paths A and C may be facilitated, for example, using hydraulic, pneumatic, electric, and/or other devices, as will be recognized by one skilled in the art. The particular mechanism(s) employed are not essential, of course, and any mechanism(s) facilitating movement along paths A and C (or any other paths described below) may be used.

In FIG. 5, the rotor **2100** has been installed within the motor **2200**. The installation may be tested using the drive motor **1400** to rotate the rotor **2100** within the stator of the motor **2200** to determine, among other things, that the rotor **2100** is properly balanced. In some embodiments, the drive motor **1400** is a variable speed motor capable of rotating the rotor **2100** from a very low speed to an operational speed.

Modifications to or variations of the system **1000** of FIGS. **1-5** may be necessary or desirable, of course, depending on the size, type, etc. of the rotor, ferromagnetic material, stator, etc. For example, rotors having a more elongate shape than that shown in FIGS. **1-5** may be more easily magnetized using a “pass-through” magnetizer that substantially surrounds all or a portion of such a rotor’s periphery at various points along its axial length. Such an embodiment is shown in FIGS. **6A-B**. In FIG. **6A**, the rotor **2102** is again attached to the arbor **1112**, which is movable along paths **A** and **C** (i.e., in substantially horizontal and vertical directions). The magnetizer **1202**, however, is adapted to surround the rotor **2102** and, upon inducing a magnetic field, to magnetize the ferromagnetic materials (not shown) within the rotor **2102**.

FIG. **6B** shows the arbor **1112** passing the rotor **2102** through the magnetizer **1202**. The magnetic field **1212** magnetizes the ferromagnetic materials, to yield a magnetized portion **2102B** of the rotor **2102**. An unmagnetized portion **2102A** of the rotor **2102**, which has yet to pass through the magnetizer **1202**, is incrementally passed through the magnetizer **1202** until the ferromagnetic materials of the entire rotor **2102** are magnetized.

Embodiments having “pass-through” magnetizers, such as that shown in FIGS. **6A-B**, may be useful in magnetizing rotors for high-speed electrical machines (HSEMs), which, due to their high rotational speed and attendant high centrifugal forces, often employ a retaining ring or similar device for securing the ferromagnetic materials within the rotor. Imparting a desired degree of magnetism to the ferromagnetic materials therefore often requires a strong magnetic field. The production of such a strong magnetic field, as well as its uniform application to the rotor, is more easily accomplished using a “pass-through” magnetizer, such as that shown in FIGS. **6A-B**.

In another aspect, the invention provides a rotor installation system having a magnet insertion device for inserting pre-magnetized ferromagnetic materials into a rotor. Thus, as with the rotor installation systems described above, such a system permits magnet insertion and rotor installation without exposure of assembly personnel to the strong magnetic forces and fields produced by large permanent magnets.

For example, FIG. **7** shows a front view of a rotor **2100** having a plurality of slots **2120A**, **2120B** . . . **2120n** spaced around its periphery. Permanent magnets are inserted into the slots **2120A-n**, after which the rotor may be balanced and inserted into a stator of a generator, motor, or other electrical machine.

FIG. **8** shows a magnet insertion device **3000** according to one embodiment of the invention. The magnet insertion device **3000** includes a body **3100** in which magnets may be contained, a plurality of passages **3110**, **3112**, **3114**, **3116**, and rods **3200A-B** capable of passing through a passage (e.g., **3114**) to insert a magnet from within the body **3100** into a slot of the rotor. The passages **3110-3116** are shown angled with respect to the body, although this is not essential. In the illustrative embodiment shown in FIG. **8**, magnet insertion is facilitated by the arbor (e.g., **1100** in FIG. **1**) rotating the rotor **2100** with respect to the magnet insertion device **3000** until a rotor slot (e.g., **2120B**) is aligned with a passage (e.g., **3112**) of the magnet insertion device **3000**. In other embodiments, the magnet insertion device **3000** may be rotated rather than, or in addition to, the rotor **2100**. A rod (e.g., **3200A**) then passes through the passage **3112** (i.e., along path **E**) to insert a magnet into the slot **2120B**. The rod **3200A** is then withdrawn and the arbor **1100** rotates the rotor **2100** until an empty slot (e.g., **2120A**) is aligned with a passage of the magnet insertion device **3000**. As noted above, hydraulic,

pneumatic, electric and/or other devices and mechanisms may be employed in rotating the rotor **2100** and/or moving the rod **3200A-B** along path **E**. Once magnets are inserted into each of the slots **2120A-n**, the rotor may be balanced and inserted into a stator, as described above with respect to FIGS. **4-5**.

In yet another aspect, the invention provides a rotor installation system having a welding apparatus for forming welded connections in rotors and the electrical machines into which the rotors are installed. FIGS. **9A-D** show one embodiment of such a system and its application. In FIG. **9A**, the rotor installation system **4000** is shown. As in the systems described above, the system **4000** includes an arbor **1114** movable along paths **A**, **B**, and **C**. To the arbor **1114** is connected a welding system **1500** comprising an elongate member **1510** and a welding device **1530**. In some embodiments, the welding device **1530** is movable about a circumference of the elongate member **1510** (i.e., along path **F**). The welding device **1530** itself includes, in some embodiments, a rotary unit **1532** for moving the welding device **1530** about the circumference of the elongate member **1510** and a welding torch **1534** for forming the welded connections. Welding devices suitable for use in such an embodiment of the invention include, for example, those available from Magnatech LLC (East Granby, Conn.), including their orbital weld heads, such as the D Weld Head model **420**. Use of such devices may require, for example, reorientation of the welding torch **1534** to face outward from rather than inward toward the elongate member **1510**. Such devices often include the ability to include a video camera, which may be useful, in some embodiments, for inspecting the welded connections made.

FIG. **9B** shows a cross-sectional view of the type of rotor or electrical machine component **2400** to which the system **4000** may be applied. Here, the component **2400** comprises a tubular member **2410** and a bellows **2420**. In this example, the bellows **2420** are to be secured to the tubular member **2410** via a welded connection on an interior of the tubular member. Other types of components and types of welded connections are also amenable to the system **4000** and are within the scope of the invention. The example given here is merely for purposes of illustration.

In FIG. **9C**, the welding system **1500** has been inserted into the tubular member **2410** such that the welding torch **1534** is positioned to form a first weld W_1 on an inner surface of the tubular member **2410**. The welding system **1500** and/or the welding device **1530** may then be rotated along paths **B** and/or **F**, respectively to extend the first weld W_1 and/or form additional welds along the inner surface of the tubular member **2410**. In FIG. **9D**, the welding system **1500** has been so rotated along path **B** to form a subsequent weld W_n .

The welding system **1500** described above may be used, for example, to form welded connections between components of a rotor, between components of a rotor and stator, or between any components of an electrical machine. The description above is given merely for purposes of illustration.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any related or incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

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What is claimed is:

1. A rotor installation system comprising:
at least one magnetizer for permanently magnetizing a ferromagnetic material; and
an arbor for receiving a rotor having at least one portion including a ferromagnetic material, the arbor being movable, during the permanently magnetizing, in both a substantially horizontal direction with substantially no movement in a vertical direction and a substantially vertical direction with substantially no movement in a horizontal direction,
wherein the at least one magnetizer is positioned relative to the arbor to allow permanent magnetization of the ferromagnetic material.
2. The rotor installation system of claim 1, further comprising:
a support for holding a generator or motor.
3. The rotor installation system of claim 2, wherein the arbor is for installing the rotor into a stator of the generator or motor.
4. The rotor installation system of claim 3, further comprising:
a drive motor for rotating the rotor within the stator after installation.

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5. The rotor installation system of claim 1, wherein the ferromagnetic material is selected from a group consisting of: iron, nickel, cobalt, aluminum alloys of iron, aluminum alloys of nickel, aluminum alloys of cobalt, ceramic mixtures containing iron, ceramic mixtures containing nickel, ceramic mixtures containing cobalt, and neodymium-iron-boron alloys.
6. The rotor installation system of claim 1, wherein the at least one magnetizer exposes substantially all of the ferromagnetic material to a magnetic field sufficient to impart to the ferromagnetic material a degree of magnetism.
7. The rotor installation system of claim 6, wherein the at least one magnetizer substantially surrounds at least a portion of the rotor.
8. The rotor installation system of claim 1, wherein the arbor moves the rotor to incrementally expose portions of the ferromagnetic material to a magnetic field sufficient to impart to the ferromagnetic material a degree of magnetism.
9. The rotor installation system of claim 8, wherein the arbor moves the rotor in at least one of the following: a peripheral direction or an axial direction.

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